

CLAIMS

1. A method of forming an inorganic compound solid by
calcining organic compounds containing metal elements,
5 comprising:

an organic substance removing step of applying organic
substance removing treatment that uses means other than heat
to organic compound materials containing metal elements,
thereby obtaining inorganic compound material; and

10 a crystallizing step of calcining to crystallize said
inorganic compound material obtained in said organic substance
removing step, thereby obtaining an inorganic compound solid.

2. The method of forming an inorganic compound solid
15 according to Claim 1, wherein said organic substance removing
step includes a depressurizing step of placing said organic
compound material in a low-pressure atmosphere.

3. The method of forming an inorganic compound solid
20 according to Claim 2, wherein said crystallizing step is carried
out after said depressurizing step.

4. The method of forming an inorganic compound solid
according to Claim 2, wherein said depressurizing step and said
25 crystallizing step are carried out simultaneously by calcining

said organic compound material in the low-pressure atmosphere.

5. The method of forming an inorganic compound solid according to any of Claims 1 through 4, wherein said organic substance removing step includes a step of giving energy other than heat to said organic compound material.

6. The method of forming an inorganic compound solid according to Claim 5, wherein said step of giving energy other than heat includes an electromagnetic wave supplying step of supplying an electromagnetic wave to said organic compound material.

7. The method of forming an inorganic compound solid according to Claim 5 or 6, wherein said step of giving energy other than heat includes a step of treating said organic compound material with activated oxygen particles.

8. The method of forming an inorganic compound solid according to any of Claims 1 through 7, wherein said inorganic compound solid is a ferroelectric.

9. The method of forming a semiconductor device according to any of Claims 1 through 8, wherein said inorganic compound solid is a complex oxide.

10. A method of manufacturing a semiconductor device,
comprising a step of forming, on a semiconductor substrate, a
functional thin film made of said inorganic compound solid by
5 the method according to any of Claims 1 through 9. ✓

11. The method of manufacturing a semiconductor device
according to Claim 10, further comprising:

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10 a restoring step of restoring characteristics
deterioration of said functional thin film caused by influences
in a step carried out after said functional thin film is formed,

said restoring step including:

a treatment step of giving energy other than heat
to said functional thin film; and

15 a heat treatment step of giving thermal energy to
said functional thin film.

12. The method of manufacturing a semiconductor device
according to Claim 11, wherein said restoring step further
20 includes an oxygen introducing step of introducing an oxidation
gas to a surface of said semiconductor substrate having formed
thereon said functional thin film.

13. The method of manufacturing a semiconductor device
25 according to Claim 11 or 12, wherein said treatment step of

giving energy other than heat to said functional thin film includes an oxygen activated particle treatment step of placing said semiconductor substrate having formed thereon said functional thin film in an oxygen activated particle
5 atmosphere.

14. The method of manufacturing a semiconductor device according to any of Claims 11 through 13, wherein said treatment step of giving energy other than heat to said functional thin
10 film includes an electromagnetic wave supplying step of supplying an electromagnetic wave to said functional thin film.

15. The method of manufacturing a semiconductor device according to any of Claims 11 through 14, further comprising
15 a wire forming step of forming a wiring on said semiconductor substrate before said restoring step.

16. The method of manufacturing a semiconductor device according to Claim 15, wherein said heat treatment step is
20 carried out such that a temperature of said semiconductor substrate does not exceed a certain temperature predetermined so as not to deteriorate said wiring.

17. The method of manufacturing a semiconductor device
25 according to any of Claims 11 through 16, further comprising

an element forming step of forming a functional element on said semiconductor substrate before said restoring step.

18. The method of manufacturing a semiconductor device
5 according to Claim 17, wherein said heat treatment step is carried out such that a temperature of said semiconductor substrate does not exceed a certain temperature predetermined so as not to deteriorate said functional element.

10 19. The method of manufacturing a semiconductor device according to any of Claims 10 through 18, further comprising an element forming step of forming a functional element on said semiconductor substrate before said step of forming said functional thin film.

15 20. The method of manufacturing a semiconductor device according to Claim 19, wherein said crystallizing step is carried out at or below a certain temperature predetermined so as not to deteriorate characteristics of said functional
20 element.

21. The method of manufacturing a semiconductor device according to any of Claims 10 through 20, wherein said crystallizing step is carried out at a predetermined
25 temperature lower than a temperature, at or above which

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mutual-diffusion of materials occurs between said functional thin film and a solid adjacent thereto.

22. The method of manufacturing a semiconductor device
5 according to any of Claims 10 through 21, wherein:

said functional thin film is a ferroelectric thin film;
and

said semiconductor device is a ferroelectric storage
device employing said ferroelectric thin film as a charge
10 holding film.

~~23.~~ A method of manufacturing a semiconductor device,
comprising:

a step of forming a functional thin film on a semiconductor
15 substrate; and

a restoring step of restoring characteristics
deterioration of said functional thin film caused by influences
during a step carried out after said functional thin film is
formed,

20 said restoring step including:

a treatment step of giving energy other than heat
to said functional thin film; and

a heat treatment step of giving thermal energy to
said functional thin film.

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24. The method of manufacturing a semiconductor device according to Claim 23, wherein said functional thin film is a complex oxide thin film.

5 ~~25.~~ The method of manufacturing a semiconductor device according to Claim 23 or 24, wherein said restoring step further includes an oxygen introducing step of introducing an oxidation gas to a surface of said semiconductor substrate having formed thereon said functional thin film.

10 ~~26.~~ The method of manufacturing a semiconductor device according to Claims 23 through 25, wherein said treatment step of giving energy other than heat to said functional thin film includes an oxygen activated particle treatment step of placing
15 said semiconductor substrate having formed thereon said functional thin film in an oxygen activated particle atmosphere.

20 27. The method of manufacturing a semiconductor device according to any of Claims 23 through 26, wherein said treatment step of giving energy other than heat to said functional thin film includes an electromagnetic wave supplying step of supplying an electromagnetic wave to said functional thin film.

25 ~~28.~~ The method of manufacturing a semiconductor device

according to any of Claims 23 through 27, further comprising a wiring forming step of forming a wiring on said semiconductor substrate before said restoring step.

5 29. The method of manufacturing a semiconductor device according to Claim 28, wherein said heat treatment step is carried out such that a temperature of said semiconductor substrate does not exceed a certain temperature predetermined so as not to deteriorate said wiring.

10 30. The method of manufacturing a semiconductor device according to any of Claims 23 through 29, further comprising an element forming step of forming a functional element on said semiconductor substrate before said restoring step.

15 31. The method of manufacturing a semiconductor device according to Claim 30, wherein said heat treatment step is carried out such that a temperature of said semiconductor substrate does not exceed a certain temperature predetermined
20 so as not to deteriorate said functional element.

 32. The method of manufacturing a semiconductor device according to any of Claims 23 through 31, wherein said functional thin film is a ferroelectric thin film.

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33. The method of manufacturing a semiconductor device according to Claim 32, wherein said semiconductor device is a ferroelectric storage device employing said ferroelectric thin film as a charge holding film.

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